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(54) METHOD FOR PAINT COLOUR CONTROL

(71) We, PFIZER, INC., a Corporation organized under the laws of the State of Delaware United States of America, of 235 East 42nd Street, New York, State of New York, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention is concerned with the color control of paint. More specifically, it is concerned with color matching and batch corrections in mimicking standard paint preparations.

Computer color matching and batch correction of paints has been used commercially for more than a decade. Traditionally, the color characteristics of the colorants used to make a paint are determined by measuring the reflectance values of dry paint films containing the colorants and calculating their absorption and scattering parameters by means of a computer program. Likewise, dry paint films are used as standards for color matching, and batches of in-process paints are prepared and measured as dry paint films to determine if the color of the batch matches the standard within established acceptance limits. If a batch is not an acceptable match for the standard, computer programs are used to predict corrective additions of colorants to the batch.

Thus, all color measurements for the purpose of establishing the color characteristics of the colorants, batch and standard are normally made on dry paint film. It is a primary objective of the present invention to provide a procedure which will eliminate this time-consuming approach to paint color control.

Previous attempts to improve on this traditional method of color matching include the measurement of wet films, as reported in the *Journal of Coatings Technology,* Vol. 48, No. 619, August 1976, page 58. This approach is not particularly satisfactory, since a wet paint film is a continuously changing system with both the medium and the pigment particles undergoing rapid changes that affect the color appearance of the system. Measurement of wet paint in bulk, which presents a more homogenous and stable system, has been suggested by I.G.H. Ishak for monitoring the color of in-process paint batches, *Journal of the Oil and Colour Chemists' Association,* Vol. 54, No. 2, February 1971 page 129. This method, however, contemplates the establishment of a correlation between the wet bulk and dry film samples for several batches of each shade of paint manufactured, a laborious and costly undertaking.

It has now been found that color matching and batch correction of paints can be easily and reliably accomplished when the color properties of the colorants, standard and batch are all determined wet in bulk.

Accordingly, the present invention entails a method for mimicking the color of a standard paint which comprises the steps of (a) determining by wet measurement the reflectance values at several wavelengths throughout the visible spectrum of the standard paint in bulk, (b) determining the optical absorption and light scattering properties of the individual colorant components of the standard paint by wet measurement of the reflectance values at several wavelengths throughout the visible spectrum of paint vehicle dispersions of the individual colorant components in bulk, (c) combining the colorant components in proportion based on their optical properties to prepare a wet paint approximately the color of the standard paint, (d) determining by wet measurement the reflectance values at several wavelengths throughout the visible spectrum of the prepared paint in bulk, and (e) introducing further amounts of at least one of the colorant components into the prepared paint in

proportions based on the optical properties of the components and on the observed discrepancies in the reflectance values of the standard and the prepared paint to adjust the color of the prepared paint to within an acceptable tolerance of the color of the standard paint.

The invention further entails a method for adjusting the color properties of a prepared paint containing at least two colorant components, to mimic the color properties of a standard paint comprising the steps of:-

(a) determining the optical absorption and light scattering properties of individual colorant components of the standard paint by wet measurement of the reflectance values at several wavelengths throughout the visible spectrum of paint vehicle dispersions of the individual colorant components in bulk,

(b) determining, by wet measurement, the reflectance values at several wavelengths throughout the visible spectrum of the standard paint and the prepared paint in bulk, and

(c) introducing an amount of at least one colorant component into the prepared paint, wherein each amount introduced is calculated using the reflectance measurements from (a) and (b) above.

In either method, the last two steps of the method may be repeated at least once to further adjust the color properties of the prepared paint to within predetermined tolerances of the color properties of the standard paint.

The methods of the present invention may be applied to the color control of all paint systems including the oil-based paints such as alkyds as well as water-based latex paint. By measuring all samples wet in bulk, these methods offer distinct advantages over the prior art approaches to color control in that they require no time delay for preparing or drying paint films, no correlation between wet and dry measurement is required, and they lend themselves to automation since all steps from measuring the colors to corrective addition of colorants can be done mechanically under computer control.

In applying the instant invention to the mimicking of the color of a standard paint, the reflectance values of the wet standard in bulk are initially determined, preferably through a glass interface, at several wavlengths throughout the visible spectrum. This determination can be readily accomplished, for example, with a spectrophotometer or abridged spectrophotometer simply by placing the wet paint in a glass cell on the instrument and reading the reflectance values of the paint at 20 nanometer intervals between wavelengths of about 400 and 700 nanometers.

The reflectance values of paint vehicle dispersions comprising the individual colorant components of the standard paint are measured in the same way as for the standard paint; preferably the dispersions are intermixes of the color components with white and with black as illustrated in the example which follows. From these reflectance values, the optical absorption and light scattering properties of the invidual colorants are determined. While a number of methods may be used for this determination, the Kubelka-Munk 2-constant (K and S) method is preferred. A discussion of this and other methods as well as a general discussion of color science may be found in D.B. Judd and G. Wyszecki, *Color in Business, Science and Industry*, third edition, 1975. The actual K and S calculations can be performed with the assistance of standard computer programs such as the IICAL program offered by Applied Color Systems, Inc. (ACS), Princeton, New Jersey.

Using the reflectance values of the standard and the optical absorption and light scattering properties of its colorant components, the proportion of the individual colorants required to produce a paint approximating the color of the standard is determined. Standard computer programs such as the ACS IIMAT can assist in this calculation. The paint is then prepared by combining the colorants in the indicated amounts, and reflectance values of the prepared wet paint in bulk are determined in the same manner as with the standard.

The color difference values between the standard and prepared paints are calculated from their reflectance values, usually for daylight illumination using CIE (Commission Internationale de l'Eclairage) Illuminant D_{65} and the standard CIE 1976 ($L^* a^* b^*$) color difference formula (CIE Publication No. 15, Supplement No. 2, May 1976). From these differences, the corrections to be made in the prepared paint composition can be calculated, assisted by such standard computer programs as ACS IICOR. The indicated additional amounts of colorants are then added to the prepared paint, and the process of comparison and correction is repeated until the color difference between the standard and prepared paints is within a predetermined limit.

In applying the instant invention to the adjustment of the color properties of a prepared paint to mimic the color properties of a standard paint, the same steps as above, with the omission of those involving the preparation of the prepared paint itself, are followed.

As indicated hereinbefore, the methods of the present invention readily lend themselves to automation. For example, when adjusting the color properties of a prepared paint to mimic the color properties of a standard paint, the colorant components can be introduced into the

prepared paint by automatic metering controlled by the reflectance measurements of the prepared paint. In one such system, a sample of the prepared paint is periodically pumped from the paint mixing tank through a flow-through glass cell where its reflectance values are measured. The reflectance values are fed to a computer which calculates the colorant additions required to bring the color of the paint within a specified tolerance of the standard paint. These colorant additions are in turn automatically metered into the mixing tank.

The following example is merely illustrative and it is not to be construed as limiting the invention, the scope of which is defined by the appended claims.

EXAMPLE

The following paints and color concentrates, manufactured by the Sherwin Williams Company, Cleveland, Ohio, were used throughout this example:

White - Dover White (K7W97) latex paint
Black - Lampblack (B43311) universal color concentrate
Yellow - Hansa Yellow L (B43Y]O) universal color concentrate
Green - Permanent Oxide Green (B43G9) universal color concentrate
Red - Dragon Red (B43R1) universal color concentrate
Clear - Latex Clear (B45VC2) latex paint

All color measurements in this example were made on a Model 400016 Diano/Hardy spectrophotometer manufactured by Diano Corporation, Mansfield, Massachussetts. The wet paint measurements were made by pouring a paint into a glass cell and measuring the color through the glass. These rectangular (55 x 35 x 10 mm) cells, made of fused optical glass, were manufactured by Hellma Cells, Inc., Jamaica, New York. Dry paint films were made by drawing down the liquid paint on cardboard supplied by the Morest Company, Inc., Freeport, New York, using a .006" (.015 cm) doctor blade. The drawdowns were allowed to dry for at least 12 hours at room temperature before their colors were measured.

The Kubelka-Munk absorption (K) and scattering (S) coefficients of the white paint and color concentrates were determined both as wet paints and dry films using intermixes of each color concentrate both with white and with black. The intermixes with white were made with 4 weight percent color concentrate for yellow and green, and 2 percent color concentrate for red and black. The intermixes with black were made with 39.6 percent color concentrate, 0.4 percent black concentrate and 60 percent clear latex paint, the clear latex (actually a translucent white in color) being employed to obtain a paint film which dried completely in less than 12 hours. The reflectance value of each of the intermixes was then measured, both wet (in the glass cell) and dry (as a drawdown), at 20 nanometer intervals between wavelengths of 400 and 700 nanometers. The K and S calculations were then performed using the calibration program (IICAL) supplied by Applied Color Systems, Inc. (ACS) Princeton, New Jersey. A specular reflection value of 4.2 percent was used for the wet color measurements while 1.7 percent was used for the dry color measurements, these values being determined by measuring several samples both with the specular component excluded and with it included. The calibrations thus resulted in two separate files of color data:

WET - K and S data for each colorant in the wet state;
DRY - K and S data for each colorant in the dry state.

Using the white paint as tinting base and the color concentrates, standard paints were prepared for color matching experiments according to the formulas given in Table I. The reflectance values of each standard paint were measured, both wet and dry, in the same manner as with the intermixes. These values were stored in a computer file for reference.

TABLE I

Standard Paint Formulas

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	1.0	1.0	---	---	98.0
Y50G50	---	1.0	1.0	---	98.0
R4YB2	0.8	0.8	---	0.4	98.0

A. *Color Matching*

Paint formulas to match each standard paint were predicted by computer using the ACS "IIMAT" program, both from the wet color measurements of the standard together with the colorant data stored in the WET file and from the dry color measurements of the standard together with the colorant data stored in the DRY file; these predicted formulas are shown in Table II.

TABLE II

Predicted Paint Formulations
for Matching Standard Paints

Based on Wet Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	1.118	1.244	-----	-----	97.637
Y50G50	-----	1.395	1.138	-----	97.467
R4Y4B2	0.827	1.021	-----	0.518	97.634

Based on Dry Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	1.075	1.436	-----	-----	97.489
Y50G50	-----	1.586	1.084	-----	97.330
R4Y4B2	0.934	1.262	-----	0.463	97.341

Paints were prepared using the predicted formulas, and their reflectance values were measured both wet and dry. Color difference values between the standard and prepared paints were then calculated for CIE Illuminant D_{65} (standard daylight light source) by the CIE 1976 ($L^* a^* b^*$) color difference formula. Table III summarizes the color difference values determined by comparing the dry drawdown of the prepared paint to the dry drawdown of the standard paint for matches predicted both from wet and from dry color measurement.

TABLE III

Color Difference Values Between Standard
and Prepared Paints

Color No.	*Prediction Basis*	*Color Difference Values* Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	Wet	0.0	1.29	-1.48	1.38
	Dry	-0.62	2.47	-0.42	2.58
Y50G50	Wet	-0.24	1.28	-0.41	1.36
	Dry	-0.56	3.34	-0.46	3.42
R4Y4B2	Wet	-2.31	-1.45	-1.45	3.09
	Dry	-1.11	1.53	-1.01	2.14

As expected, the prepared paints were off-shade because of the limitations of the Kubelka-Munk theory and the calibration procedure. However, the predictions based on wet measurement were as accurate as those based on dry measurement.

The paints prepared by prediction based on wet measurement were also compared in bulk with the standard paints in bulk. Table IV shows that color difference values obtained by comparing a wet sample to a wet standard correlate well with color difference values obtained by comparing a dry sample to a dry standard.

TABLE IV

Comparison of Standard Paints with Paints
Prepared by Wet Measurement Prediction

Color No.	*Type of Measurements*	*Color Difference Values* Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	Wet Bulk	0.12	1.05	-0.51	1.17
	Dry Film	0.00	1.29	-0.48	1.38
Y50G50	Wet Bulk	-0.30	1.05	-0.35	1.14
	Dry Film	-0.24	1.28	-0.41	1.36
R4Y4B2	Wet Bulk	-1.55	-1.14	-1.22	2.28
	Dry Film	-2.31	-1.45	-1.45	3.09

Corrections for the prepared paint formulas were calculated using the ACS "IICOR" program. The corrections for the wet formulation paints were based on wet measurement of the standards and the initial formulations together with the colorant data stored in the WET

file, while those for the dry formulation paints were based on dry film measurement of the standards and the initial formulations together with the colorant data stored in the DRY file. The corrected paint formulations were then prepared, measured both wet and dry, and compared to the standards. The corrected formulations are shown in Table V, while the color difference values between the dry drawdowns of the standard and corrected paints are summarized in Table VI.

TABLE V
Corrected Paint Formulations
for Matching Standard Paints

Based on Wet Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	1.037	1.043	-----	-----	97.920
Y50G50	-----	1.211	1.057	-----	97.732
R4Y4B2 (1)	1.015	1.069	-----	0.364	97.553
R4Y4B2 (2)	0.892	0.881	-----	0.367	97.851

Based on Dry Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	1.044	1.080	-----	-----	97.876
Y50G50	-----	1.143	1.049	-----	97.807
R4Y4B2	0.920	0.930	-----	0.394	97.756

TABLE VI
Color Difference Values Between Standard
and Corrected Paints

Color No.	*Prediction Basis*	*Color Difference Values* Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	Wet	-0.03	-0.04	-0.12	0.13
	Dry	-0.13	0.41	-0.17	0.47
Y50G50	Wet	0.12	0.75	-0.12	0.77
	Dry	0.20	-0.07	-0.03	0.21
R4Y4B2	Wet (1)	0.47	1.03	0.08	1.14
	Wet (2)	0.00	-0.10	0.03	0.10
	Dry	-0.14	-0.14	-0.16	0.25

Based on experience and visual observation, an acceptable match was defined as one having $\Delta E \leq 1.0$ CIE $L^*a^*b^*$ unit. Table VI shows that wet measurement is as capable of predicting acceptable paints as dry measurement. In the case of R4Y4B2, the wet prediction required a second correction to bring the paint within the acceptable limit. In present practice when working with dry drawdowns, it is not uncommon to use two corrections to obtain a close match. The fact that two corrections were required for R4Y4B2 is therefore not considered significant.

B. *Batch Correcting*

New batches of the standard paints were prepared using the same formulas as in Table I but employing different lots of the color concentrates and the white tinting base. As expected, the colors of the new batches did not match the colors of the original standards because of lot-to-lot variations in the colors of the components. Table VII gives the color differences between the original standard paints and the new batches.

TABLE VII

Color Difference Values Between New Batches and Original Standard Paints

Wet Batch Compared to Wet Standard

Color No.	Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	0.51	-1.03	0.08	1.15
Y50G50	0.89	-1.50	0.34	1.77
R4Y4B2	-0.27	-1.54	-0.28	1.58

Dry Batch Compared to Dry Standard

Color No.	Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	0.56	-1.21	-0.01	1.34
Y50G50	1.11	-1.33	0.24	1.75
R4Y4B2	-0.67	-2.18	-0.21	2.29

Using the ACS "IICOR" program, batch corrections were preducted both from the wet color measurements of the original standard and the new batch together with the colorant data stored in the WET file, and from the dry color measurements of the original standard and the new batch together with the colorant data stored in the DRY file. These batch corrections were made and the reflectance values for the corrected batches were measured both wet and dry. The corrected batch formulations are listed in Table VIII, while the color difference values between the dry drawdowns of the corrected batches and the original standard paints are shown in Table IX.

TABLE VIII

Corrected Batch Formulations

Based on Wet Color Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	0.988	1.167	-----	-----	97.846
Y50G50	-----	1.160	1.304	-----	97.535
R4Y4B2	0.862	1.032	-----	0.354	97.752

Based on Dry Color Measurement

Color No.	*% Red*	*% Yellow*	*% Green*	*% Black*	*% White*
R50Y50	0.980	1.151	-----	-----	97.869
Y50G50	-----	1.110	1.347	-----	97.543
R4Y4B2	0.906	1.071	-----	0.348	97.675

TABLE IX

Color Difference Values Between Corrected Batches and Original Standard Paints

Color No.	*Predicition Basis*	*Color Difference Values* Δa^*	Δb^*	ΔL^*	ΔE
R50Y50	Wet	0.23	-0.60	-0.21	0.68
	Dry	0.00	-0.49	0.14	0.51
Y50G50	Wet	0.43	-0.63	-0.57	0.94
	Dry	0.34	-1.04	-0.68	1.29
R4Y4B2	Wet	0.08	-0.20	0.51	0.56
	Dry	0.06	-0.42	0.09	0.43

Within the limits of sample preparation repeatability, there is no significant difference in accuracy between the wet-predicted and the dry-predicted corrections. Indeed, the dry match for Y50G50 is outside of the defined acceptance limit, and the computer predicted that no further improvement of this match was possible with the colorants available.

6

WHAT WE CLAIM IS:-

1. A method for adjusting the color properties of a prepared paint containing at least two colorant components, to mimic the color properties of a standard paint comprising the steps of:-

(a) determining the optical absorption and light scattering properties of individual colorant components of the standard paint by wet measurement of the reflectance values at several wavelengths throughout the visible spectrum of paint vehicle dispersions of the individual colorant components in bulk,

(b) determining, by wet measurement, the reflectance values at several wavelengths throughout the visible spectrum of the standard paint and the prepared paint in bulk, and

(c) introducing an amount of at least one colorant component into the prepared paint, wherein each amount introduced is calculated using the reflectance measurements from (a) and (b) above.

2. The method of claim 1 wherein said steps (b) and (c) are repeated at least once to further adjust the color properties of said prepared paint to within predetermined tolerances of the color properties of said standard paint.

3. The method of claim 1 wherein said reflectance measurements are made through a glass interface.

4. The method of claim 1 wherein said reflectance measurements are made at intervals of 20 nanometers between wavelengths of about 400 and 700 nanometers.

5. The method of claim 1 wherein said colorant components are introduced into said prepared paint by automatic metering controlled by reflectance measurements of said prepared paint.

6. A method for mimicking the color of a standard paint which comprises the steps of (a) determining by wet measurements the reflectance values at several wavelengths throughout the visible spectrum of said standard paint in bulk, (b) determining the optical absorption and light scattering properties of the individual colorant components of said standard paint by wet measurement of the reflectance values at several wavelengths throughout the visible spectrum of paint vehicle dispersions of said individual colorant components in bulk, (c) combining said colorant components in proportion based on said optical properties to prepare a wet paint approximately the color of said standard paint, (d) determining by wet measurement the reflectance values at several wavelengths throughout the visible spectrum of said prepared paint in bulk, and (e) introducing further amounts of at least one of said colorant components into said prepared paint in proportions based on said optical properties of said components and on the observed discrepancies in said reflectance values of said standard and said prepared paint to adjust the color of said prepared paint to within acceptable tolerances of the color of said standard paint.

7. The method of claim 6 wherein said steps (d) and (e) are repeated at least once to further adjust the color of said prepared paint to within predetermined tolerances of the color of said standard paint.

8. A paint which has had its color properties adjusted according to a method as claimed in any one of claims 1 to 7.

STEVENS, HEWLETT, & PERKINS,
Chartered Patent Agents,
5, Quality Court,
Chancery Lane,
London W.C.2

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